Heat Transfer Properties of Structured Packings for Biofuel Production via Fischer-Tropsch Synthesis

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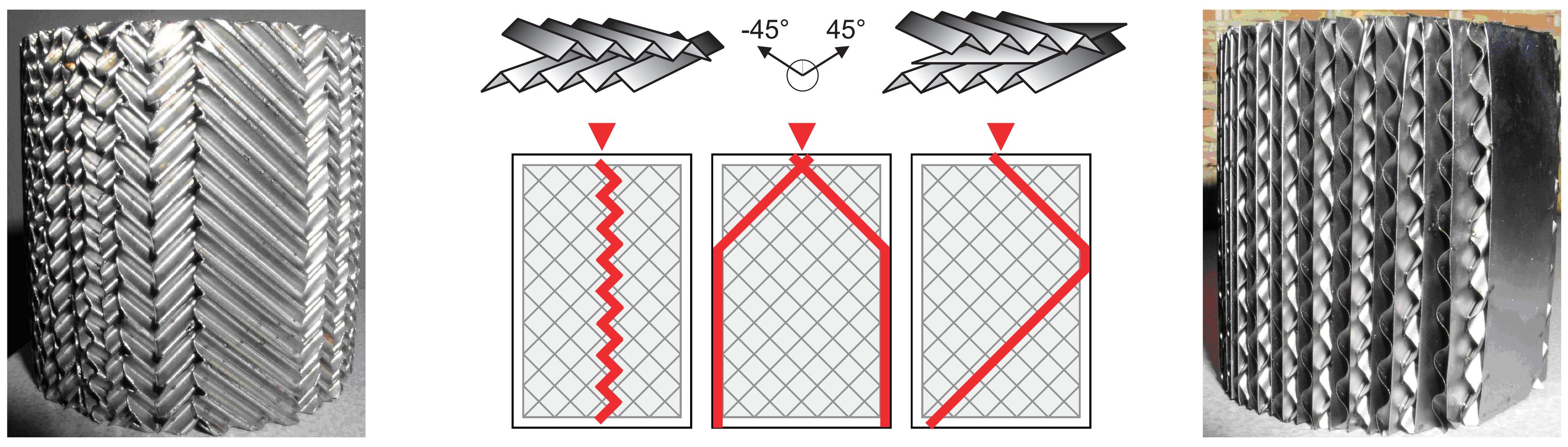
Introduction

Structuring a reaction environment has been found to have many benefits [1], including reactor performance improvements. This mainly results from improved heat and mass transfer characteristics of structured flow profiles. The Fischer-Tropsch process is a system that is very eligible for this development; not only from an engineering point of view [2], but also from a sustainable point of view [3]. In this project we aim to develop a structured reaction environment for a multi-tubular fixed bed reactor to significantly improve the Fischer-Tropsch process.

Structured packings



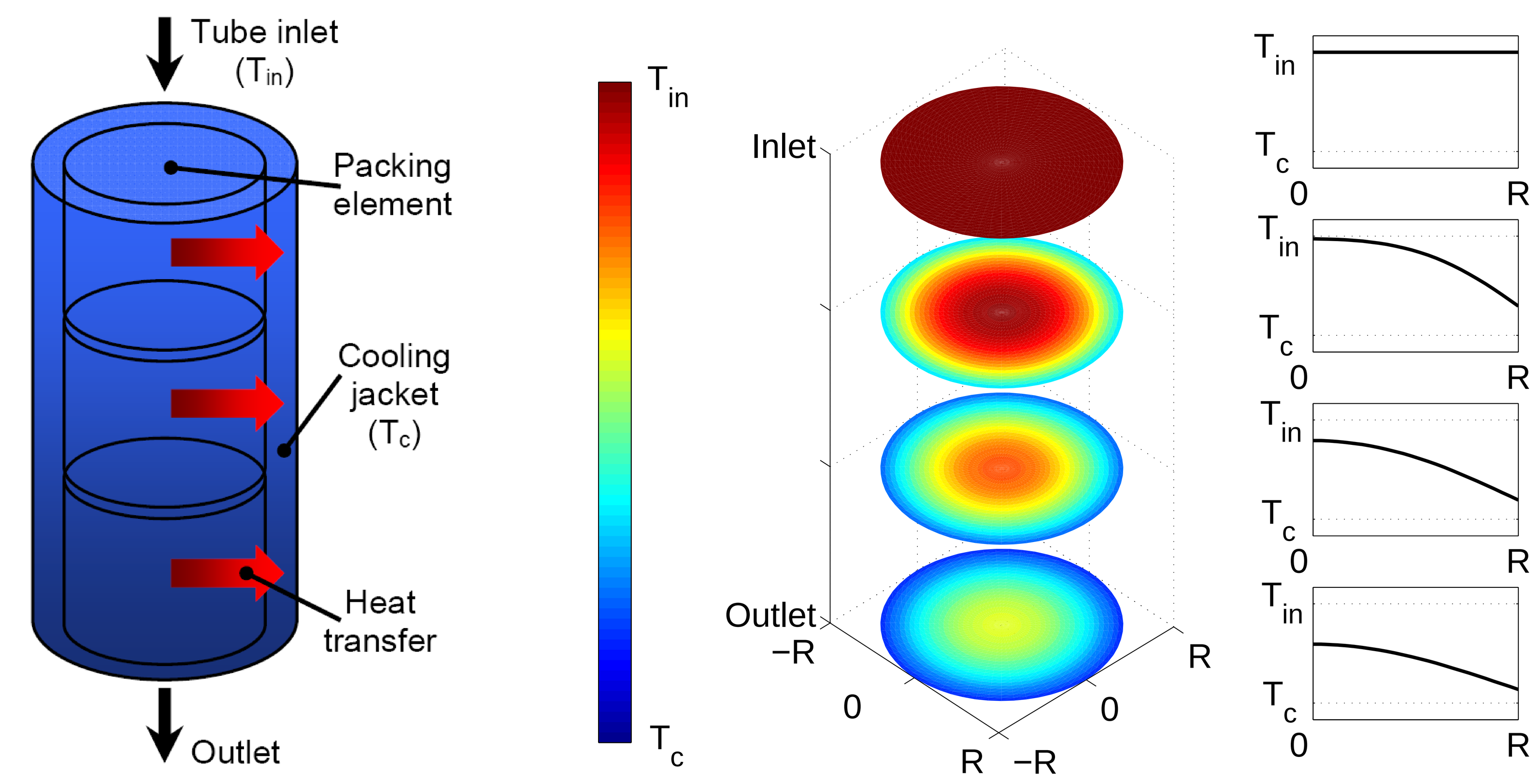
Open (left) and Closed (right) Cross Flow Structure

Heat transfer theory

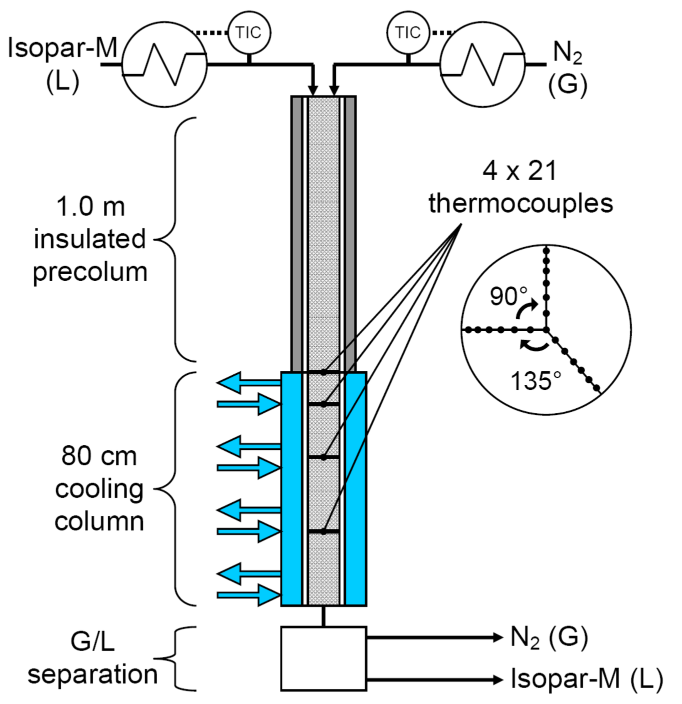
The temperature profile in the tube is described by the two dimensional pseudo-homogeneous plug flow model, which includes the effective radial heat transfer ($\lambda_{e,r}$) and the wall heat transfer (α_w) coefficients:

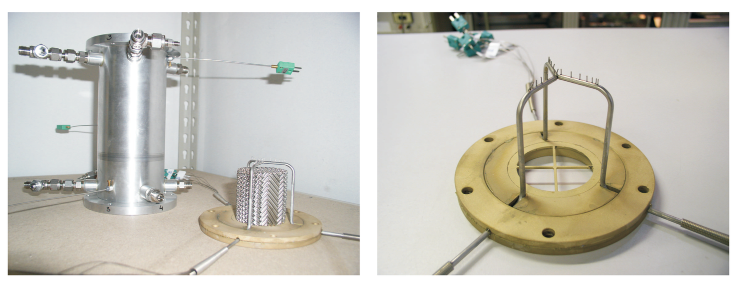
$$\rho u C_p \frac{\partial T}{\partial z} = \lambda_{e,r}\left\{\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r}\right\}$$

$$z = 0: \quad T = T_{in}$$
$$r = 0: \quad \frac{\partial T}{\partial r} = 0$$
$$r = R: -\lambda_{e,r}\frac{\partial T}{\partial r} = \alpha_w\{T_{r=R} - T_w\}$$



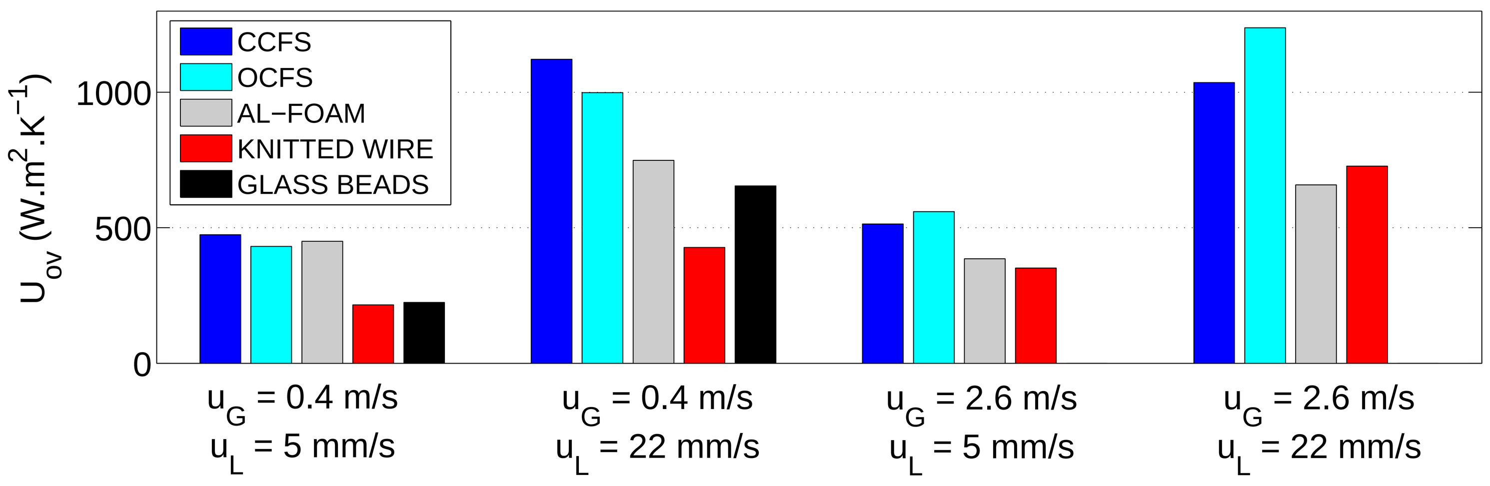
Set-up





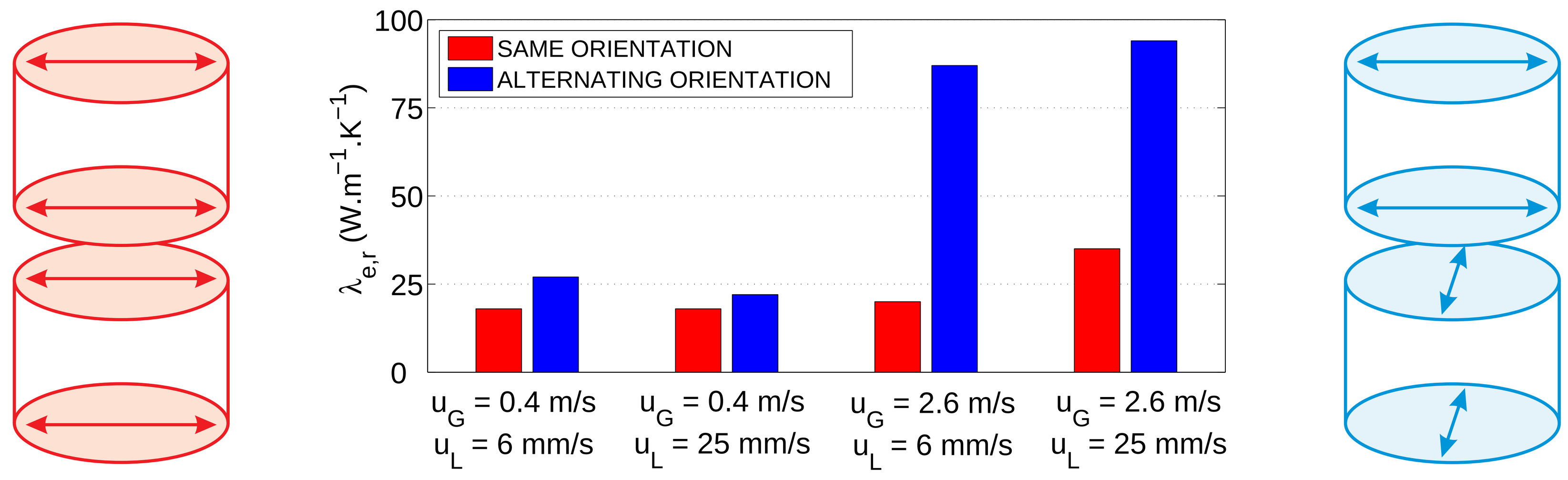
- Two-phase system
- Controllable flowrates
- No reaction
- 100+ thermocouples
- 36 packing elements

Results



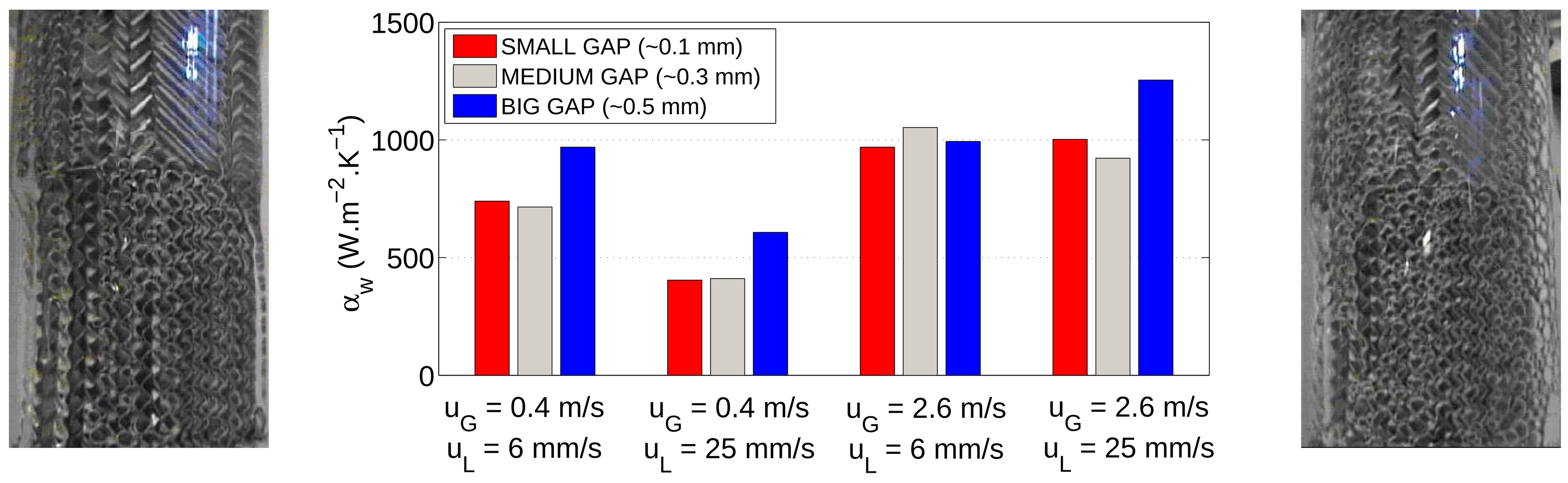
The overall heat transfer (U_{ov}) of OCFS and CCFS packings is significantly larger than that of other packings.

Anisotropy



Same orientation stacks (left) of OCFS packings show a reduced effective radial heat transfer ($\lambda_{e,r}$) compared to alternating orientation stacks (right).

Wetting of the gap



Less wetting of the small gap (left) in OCFS packings reduces the wall heat transfer coefficient (α_w) compared to that of the big gap (right).

Conclusions

OCFS and CCFS packings perform much better than other (random) packings in terms of heat transfer, primarily as a consequence of the large effective radial heat transfer properties ($\lambda_{e,r}$). Also, incomplete wetting of the gap between the packing and the cooling wall plays an important role in heat transer.

Future work

Optimization of the packing involves research (experimental and modelling) in: RTD, channel angle, and channel size. The performance will be quantified by the results of both heat- and mass transfer characteristics.

References

1. K. Pangarkar, T.J. Schildhauer, J.R. van Ommen, J. Nijenhuis, F. Kapteijn, J.A. Moulijn, "Structured Packings for Multiphase Catalytic Reactors", Ind. Eng. Chem. Res. 2008, 47, 3720-3751.
2. R.M. de Deugd, F. Kapteijn, J.A. Moulijn, "Trends in Fischer-Tropsch reactor technology-opportunities for structured reactors, Topics in Catalysis", 26, 1-4, December 2003.
3. A. Demirbas, "Biofuels sources, biofuel policy, biofuel economy and global biofuel projections", Energy Conversion and Management, 49, 2106-2116, 2008.

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